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LOAD CHANGE SAFETY SYSTEM

[0001] This invention relates to a system designed to keep the operator **30** and/or other individuals safe from the hazardous condition of a lowering stacking deck **3,3'** of a sheet stacker **2,2'**. The hazardous condition is the variable pinch point gap **9,9'** created between the discharge end **4,4'** of the stacking deck **3,3'** and a conveying sheet material removal system **7,7'** typically located under the discharge end **4,4'** of the sheet stacker **2,2'**. The conveyor system provides means for transporting material away from the sheet stacker **2,2'**. The need for the load change safety system **1-1''''** is amplified by the fact that the operator **30** and/or other individuals are required to frequently go near the hazardous area of the variable pinch point gap **9,9'** during normal production operation to place protective sheets, referred to as dunnage **50** and/or pallets **51** on the conveying sheet material removal system **7,7'** before each sheet stack **6** is created at the discharge end **4,4'** of the sheet stacker **2,2'**.

[0002] The term operator **30** used throughout this patent shall be interpreted to include not only the person operating the sheet stacker **2,2'** but also any and all other people that come near or in contact with the sheet stacker.

[0003] The term LCS system is used in this patent to refer to the Load Change Safety System.

Background of the invention

[0004] It is common to stack cardboard/corrugated sheet stacks **6** into full stacks **52**, which are then conveyed in a straight line by a floor conveyor (typically top of conveyor rollers approximately 12 inches above the floor) to another machine. These full stacks **52** are often created by first placing down a pallet **51** and/or a protective sheet on said sheet material removal system **7,7'**. These protective sheets are often referred to as dunnage **50** in the industry. The pallet **51** and/or dunnage **50** provides protection for the

bottom sheets of the full stacks **52** and/or allow machinery down stream (typically fork lift trucks) to be able to handle the full stacks **52**.

[0005] One form of sheet stacker **2** found in U.S. 2,901,250 granted to Martin on August 25, 1959. The sheet stacker is typical of a class of stackers referred to as "upstackers" in the industry since they create a full stack **52** by using a stacking deck **3** which articulates in such a way that the receiving end has little or no vertical motion and the discharge end **4** has adequate motion to create full stacks **52** while moving in a generally upward motion. The cardboard/corrugated is transported on a plurality of conveyor belts built into the stacking deck **3** from the receiving end of the stacking deck **3** to the discharge end **4** of the stacking deck **3**.

[0006] A second form of sheet stacker is found in U.S. 5,026,249 granted to TEI on June 25, 1991. The sheet stacker is typical of a class of stackers referred to as a "downstackers" in the industry since they create a full stack **52** by elevating and lowering the sheet material removal system **7'** under a fixed stacking deck in such a way that the receiving end and discharge end of a stacking deck has no motion but the elevating conveyor lowers as the sheet stack **6** is created in order to create full stacks **52**.

[0007] A third form of sheet stacker is a hybrid where both the stacking deck **2** and sheet material removal system **7'** can move in their prescribed motion in order to create the sheet stacks **6**.

[0008] It is also common to stack cardboard/corrugated sheets into short sheet stacks **6** referred to as bundles in the industry. The bundles are typically created at the discharge end **4,4'** of the sheet stacker **2,2'** on some sort of conveyor roller or conveyor belt system, which is typically referred to as a bundle takeaway system. Typical bundle takeaway systems are waist high in order to allow the operator to manually manipulate the bundles down stream.

[0009] In both situations where full stacks **52** or bundles are being created, the sheets are stacked during the motion by which the variable pinch point

gap **9,9'** between the discharge end **4,4'** of the stacking deck **3,3'** is increasing. Once a full stack **52** or bundle has been created, it must be transported from under the discharge end **4,4'** of the sheet stacker **2,2'** . While the full stack(s) **52** or bundle(s) is being transported, an accumulation device **54** is often employed to collect sheetmaterial **5** so as to allow material to continue to fall off the end of the stacking deck **3,3'** while waiting for the full stack **52** or bundle to be transported and allowing the stacking deck **3,3'** and/or sheet material removal system **7,7'** to move towards each other, thus decreasing the variable pinch point gap **9,9'** . One form of accumulation device **54** is found in U.S. 6,042,108, Morgan et al, granted March 28, 2000. The variable pinch point gap must decrease in a relatively fast motion approximately 4-5 seconds on full stacks **52** and 1-2 seconds on bundles in order to keep the material collecting in the accumulator area **55** from exceeding the designed capacity of the accumulation device **54** . The ejecting of a sheet stack and reduction of variable pinch point gap **9,9'** so next sheet stack can be built is commonly referred to as the load change cycle **56** in the industry.

[0010] This rapid motion of the stacking deck **3** and/or sheet material removal system **7'** to within close proximity results in a hazardous condition where the variable pinch point gap **9,9'** is formed between the bottom side of the discharge end **4,4'** of the stacking deck **3,3'** and the sheet material removal system floor conveyor or bundle takeaway system. Due to the weight and strength of the machinery, a person caught in this variable pinch point gap **9,9'** may have the result of serious injuries or death.

[0011] The open design of the stacking deck **3,3'** is a major productivity advantage of the sheet stacker **2,2'** . During normal production it is important that the operator **50** have easy access to the discharge end **4,4'** of the stacking deck **3,3'** . This invention targets the production operations performed by the operator. The production operations includes setting up the

order, running the order, adjusting the order, checking for quality control purposes, placing dunnage **50** and/or pallets **51** , clearing jams and placing stack identification tags into full stacks **52** . While executing production operations the operator must be able to have access to the discharge end **4,4'** of the stacking deck **3,3'** without completely de-energizing and re-energizing the machinery since this would have a substantial impact on production.

[0012] The maintenance/clean up operations performed by the operator **30** and other employees is a different type of operation. Unlike the production operation where one individual is responsible for the area around the discharge end **4,4'** of the stacking deck **3,3'**, the maintenance/clean up operations may involve one or more people sometimes working on key systems including the hydraulic, pneumatic and electrical systems. Most companies owning sheet stacking machinery have already established procedures, commonly referred to as Zero Energy State and/or Lock-Out-Tag-Out. These procedures require too much recovery time to use as a safety solution during production operations.

[0013] The ability of the stacking deck **3** and/or sheet material removal system **7'** to be able to execute a load change cycle **56** fully automatically without the assistance of the operator is often a required productivity feature of a sheet stacker **2,2'** . Prior to this invention, some sheet stacker **2,2'** owners have elected to eliminate the ability of the operator to execute a load change cycle **56** fully automatically. These sheet stackers **2,2'** may require the operator to manually initiate the stacking deck **3,3'** down motion or to depress some sort of push button during the entire time the variable pinch point gap **9,9'** is decreasing. Even if this does not hinder the productivity due to the configuration of the sheet stacker **2,2'** production line, this solution still may not meet the guidelines of the International Safety Standards which include redundancy and self-testing.

[0014] A light guard system for this type of sheet stacker **2,2'** has been available since 1990 as provided by the Geo. M. Martin Co., see Figure 1-4.

However, this system has many short comings including 1) lack of a fail-safe mode should a single component fail, 2) no self testing, 3) difficult installation and maintenance due to stringent mirror alignment requirements, 4) lack of flexibility when needing multiple mirrors to reflect the light, 5) no fault detection of cross talk from external optical sources, 6) interference due to light stand locations and 7) not able to run fully automatic cycling of full stacks **52** when the sheet stacker **2,2'** is equipped with an automatic dunnage **50** and/or pallet **51** system.

Summary of the Invention

[0015] The Load Change Safety System **1-1''''** of the present invention is a safety system to keep the operator **30** a safe distance from the variable pinch point gap **9,9'** while the sheet stacker **2,2'** is performing the load change cycle **56**, hence achieving the very important objective of keeping the operator **30** from accidentally getting near or in the variable pinch point gap **9,9'** while decreasing.

[0016] Another objective of the present invention is to provide hydraulic redundancy by including a rigid stacking deck **3** with dual cylinders **11,12**, dual hydraulic lock valves **13,14** so that a single component failure in the hydraulic system will not allow the stacking deck **3** to initiate or continue the deck down cycle.

[0017] A further objective of the present invention is to provide the ability to perform self- testing on the hydraulic system by adding feedback sensors **18,19** to allow detection of a hydraulic leak and/or failure.

[0018] A further objective of the present invention is to provide a robust light guard system **27** by using a series of optical repeating nodes **24** instead of mirrors to reduce the requirements for precise alignment and the accumulation of accuracy error when needing to create a light guard perimeter **21** in which the beam(s) of light must be redirected multiple times. This light guard system **27** may be operatively connected to the LCS system control means

15'',15''' and the hydraulic lock valves **13,14** to place both valves in a state which does not allow the variable pinch point gap **9,9'** to decrease.

[0019] A further objective of the present invention is to define a configuration of a light guard system **27** by which the optical repeating node **24'** on the operator side of the sheet stacker **2,2'** near the discharge end **4,4'** of the stacking deck **3,3'** is part of a movable remote control mean **35** in order to reduce the interference that would be caused if a floor mounted optical repeating node **24** was located in the same general proximity.

[0020] A further objective of the present invention is to modulate optical signals on the light beams **20,20'** of the light guard system **27** in order to substantially increase the likelihood that any failure in the electrical and/or optical circuit is interpreted as a light guard system **27** intrusion and results in a fail-safe mode.

[0021] A further objective of the present invention is to configure the relationship between the sheet stacker **2,2'** , sheet material removal system **7, 7'** and the location where the light guard perimeter **21** crosses over the sheet material removal system **7, 7'** in such a manner to allow synchronized discharge of the full stacks **52** and fully automatic completion of the load change cycle **56** .

Brief Description of Drawings

[0022] FIG 1 is a prior art plan layout of a safety light beam system **100** provide by Geo. M. Martin Co. around 1990 for an upstacking sheet stacker **2.**

[0023] FIG 2 is a side view of Figure 1.

[0024] FIG 3 is a prior art plan layout of a safety light beam system **100** provided by Geo. M. Martin Co. around 1990 for a downstacking sheet stacker **2'.**

[0025] FIG 4 is a side view of Figure 3.

[0026] FIG 5 shows a variable pinch point gap **9** for an upstacking sheet stacker **2** of the present invention with a substantial pinch point gap.

[0027] FIG 6 is a zoomed in view of Figure 5.

[0028] FIG 7 is a variable pinch point gap **9** for an upstacking sheet stacker **2** of the present invention with minimal pinch point gap.

[0029] FIG 8 is a zoomed in view of Figure 7.

[0030] FIG 9 is a variable pinch point gap **9'** for an downstacking sheet stacker **2'** of another form of the present invention with a substantial pinch point gap.

[0031] FIG 10 is a zoomed in view of Figure 9.

[0032] FIG 11 is a variable pinch point gap **9'** for a downstacking sheet stacker **2'** of the present invention with minimal pinch point gap.

[0033] FIG 12 is a zoomed in view of Figure 11.

[0034] FIG 13 is a sequence of cycles that create the load change cycle **56** for the upstacking sheet stacker **2** shown in Figure 5.

[0035] FIG 14 is a perspective view of a sheet stacker **2** of the present invention showing the substantially rigid stacking deck **3** supported by a pair of hydraulic cylinders **11,12**.

[0036] FIG 15 is an alternative perspective view of the sheet stacker **2** of Figure 14 showing the substantially rigid stacking deck **3** emphasizing the stacking deck **3** construction..

[0037] FIG 16 is an inside side view if a portion of the sheet stacker **2** taken in the general direction of line 16-16 with portions of the sheet stacker removed to more clearly show the stacking deck **3** and portions of the redundant means **10** , specifically one of two hydraulic cylinders **12** hydraulic lock valves **14** and self testing limit switch assemblies including hydraulic position sensors **18** are shown.

[0038] FIG 17 is a zoomed in view of a portion of Figure 16

[0039] FIG 18 is a schematic cross sectional view of Figure 15 taken along line 18-18 when both cylinders **11.12** are providing support to stacking deck **3** activating hydraulic self testing limit switches **18,19**.

[0040] FIG 19 is a schematic cross sectional view of Figure 15 taken along line 18-18 when stacking deck **3** is in a different position and only one cylinder **11** is providing support to stacking deck **3** activating only one hydraulic self testing limit switch **19** showing the 'racking effect' of the substantially rigid stacking deck **3** .

[0041] FIG 20 is basic LCS system control means **15** hydraulic and electrical schematic for an upstacking sheet stacker **2**

[0042] FIG 21 is basic LCS system control means **15'** hydraulic and electrical schematic for an downstacking sheet stacker **2'**

[0043] FIG 22 is a schematic of a typical optical circuit required to create a light guard around a sheet stacker **2,2'** using light beam transmitter **22** , light beam receiver **23** and a plurality of optical repeating nodes **24, 24'** of the present invention to redirect the light.

[0044] FIG 23 is a side view of Fig. 22

[0045] FIG 24 is a detail view of an optical repeating node **24,24'** .

[0046] FIG 25 is a schematic of a typical optical circuit that would be required to create a light guard around a sheet stacker **2,2'** using one transmitter, one receiver and a plurality of mirrors to redirect the light.

[0047] FIG 26 is a detail view of a mirror **86** in Figure 25

[0048] FIG 27 is a detail view of a mirror **86'** in Figure 25

[0049] FIG 28 is a detail view of a mirror **86''** in Figure 25

[0050] FIG 29 is a detail view of a mirror **86'''** in Figure 25

[0051] FIG 30 is a detail view of a mirror **86''''** in Figure 25

[0052] FIG 31 is the light guarded LCS system control means **15''** hydraulic and electrical schematic for an upstacking sheet stacker **2**

[0053] FIG 32 is the light guarded LCS system control means **15'''** hydraulic and electrical schematic for a downstacking sheet stacker **2**

[0054] FIG 33 is a schematic describing how the light guard system modulated self test and fault detection operates.

[0055] FIG 34 is a perspective view of a sheet stacker **2** without a boom in which a light guard perimeter is created by using a floor mounted optical repeating node **24** in close proximity to where the operator **30** normally works.

[0056] FIG 35 is a perspective view of a sheet stacker **2** with a boom in which a light guard is created by mounting the optical repeating node **24'** on the boom which is in close proximity to where the operator **30** normally works.

[0057] FIG 36 is the same as Fig. 35 but with the boom moved out of the way.

[0058] FIG 37 is a layout showing a typical installation configuration of a light guard system in which the full stack **6'** is transported from within the light guard perimeter **21** to outside the light guard system before the impending deck down cycle **56''** is initiated.

[0059] FIG 38 is a layout showing a typical installation configuration of a light guard system configured to perform a synchronized discharge in which the full stack **6'** is transported in such a way that the full stack **6'** stays within the light guard perimeter **21** and allows the deck down cycle **56''** to be completed before either manually or automatically being release for further transport from inside the light guard perimeter **21** to outside the light guard perimeter **21**.

[0060] FIG 39 is a conveying system control means **92** represented in schematic form

[0061] FIG 40 is a layout showing a typical installation configuration of a light guard system configured to perform a synchronized discharge in which multiple full stacks **6',6''** are transported in such a way that the full stacks stays within the light guard system and allows multiple deck down cycles **56''** to be completed before either manually or automatically being release for further transport from inside the light guard perimeter **21** to outside the light guard perimeter **21**.

<u>**Description of the Invention**</u>

[0062] In the present invention, a load change safety system **1-1'''** is provided for a sheet stacker **2,2'** in which a variable pinch point gap **9,9'** is created during the load change cycle **56** due to the motion of the stacking deck **3,3'** and/or the conveying sheet material removal system **7,7'** . The variable pinch point gap **9** can be created with an "upstacker" type of sheet stacker **2** where the stacking deck **3** moves in a generally upward direction, while the conveying sheet removal system **7** remains fixed, as illustrated in Figures 5, 6, 7 & 8. Alternatively, the variable pinch point gap **9'** can be created with a "downstacker" type of sheet stacker **2'** where the stacking deck **3'** remains fixed, while the conveying sheet removal system moves in a generally downward direction, as illustrated in Figures 9, 10, 11 & 12.

[0063] The sheet stacks **6** are first created as the sheet material **5** exits the discharge end **4,4'** of the stacking deck **3,3'** and the variable pinch point gap **9,9'** increases. This increase in said variable pinch point gap keeps the relative distance between the elevation at which the sheet material **5** exits the discharge end **4,4'** of the stacking deck **3,3'** and top of the sheet stack **6** approximately the same while the height of the sheet stack **6** increases. Once the sheet stack **6** has been created, it is necessary to perform a load change cycle **56** .

[0064] The load change cycle **56**, illustrated in Figure **13** first requires load ejection cycle **56'** in which the sheet stack **6'** is transported downstream on the conveying sheet material removal system **7,7'** using rollers **57** or belts. Often, during this period an accumulation device **54** is used to allow the sheet material **5** to continue to exit the discharge end **4,4'** and the stacking deck **3,3'**. After the load ejection cycle **56'** is the deck down cycle **56''** in which the variable pinch point gap **9,9'** is decreased by motion of the stacking deck **3** down and/or motion of the conveying sheet material removal system **7'** up. Once the deck down cycle **56''** is completed, the accumulation device **54** retracts transferring the beginning of the next sheet stack **6''** from

the accumulation area **55** to the receiving means **8,8'** of the conveying sheet material removal system **7,7'**.

[0065] In the present invention, redundant means **10** including, e.g., hydraulic cylinders **11,12** , valves **13,14** and LCS system control means **15** as shown in Figures 17,18, and 20, are provided to selectively prevent the decrease of the variable pinch point gap **9,9'** to reduce the chances of an operator **30** being hurt.

[0066] An upstacking sheet stacker **2** has a variable pinch point gap **9** which decreases as shown by two positions, first in Figure 6 and then in Figure 8. This is due to gravities affect on the moveable stacking deck **3** . Figures 14 & 15 show two different perspective views of a typical upstacker stacking deck **3** . In this preferred embodiment, you will note the rear deck **58** is constructed using side wall members **59, 59'** and cross torque tubes **60, 60'** such that the box frame created forms a planer surface **61** . Since the cross torque tubes **60, 60'** are able to resist torque, typically made from rectangular tubing, the rear deck **58** is a substantially rigid structure that attempts to keep planer surface 61 flat when rigidly pinned for pivoting by swing arms **62, 62'**. The four bar linkage created by the rear deck **58** , swing arms **62,62'**, the stacker base **63** and lifting arms **64, 64'** creates a nearly straight vertical motion at the discharge end **4** of the stacking deck **3** when the lifting arms **64,64'** are operably connected to support hydraulic cylinders **11,12** . In Figures 14 & 15 the side casting **65** opposite **65'** has been removed for clarity but may be seen in Figure 18. The hydraulic cylinders **11, 12** provide redundant support, due to the existence of the substantially rigid structure created by the rear deck **58** and the fact that either hydraulic cylinder **11** or **12** is capable of supporting the weight of the entire stacking deck **3**. Should either cylinder fail to provide support, the deck will 'rack' slightly as the planer surface **61** warps slightly, but the deck does not come down substantially.

[0067] In Figure 16 & 17 are detail side views of the sheet stacker **2** when viewed from line 16-16 of Figure 15. It shows the left side casting **65'** , left

stacker lifting arm **64'** and left hydraulic cylinder **12** connecting stacker base frame **63'** to left stacker lifting arm **64'**. If oil flows into left hydraulic cylinder port **66** , the left hydraulic cylinders **12** rod extends **94** increasing the variable pinch point gap **9**. Likewise, due to gravity, oil is naturally pressurized at all time to flow out of left hydraulic cylinder port **66**. Connected to left hydraulic cylinder port **66** is first a left hydraulic velocity fuse **68**. The left hydraulic velocity fuse **68** has a feature of locking up and stopping oil from exiting left hydraulic cylinder port **66** should the flow rate exceed a certain designed threshold; typically to keep a hydraulic line blowout from causing damage. While not required for the present invention, including a hydraulic velocity fuse **67, 68** on each cylinder is considered good practice. Then, connected to the left hydraulic velocity fuse **68** is hydraulic lock valve **14** which will let oil into hydraulic cylinders **12** via check valve but will only let oil out of hydraulic cylinder port **66** only if hydraulic lock valve solenoid **70** is energized. There is a separate and independent right hydraulics lock valve **13** connected in a redundant fashion to right hydraulic cylinders **11**. The result is two independent and redundant support means or systems **10** , with both right hydraulic lock valve solenoid **69** and left hydraulic lock valve solenoid **70** needing to be activated in order to allow a narrowing of variable pinch point gap **9** .

[0068] The LCS system control means **15** shown in fig 20 allows the operator **30** to press a deck down enabled button **71** in order to electrically activate redundant hydraulic lock valve solenoids **69, 70** . Said deck down enabled button **71** has redundant right and left deck down enabled contacts **72, 73** that will conduct electrical power down redundant paths to self testing means **74,75** which then may conduct to fault detection means **76, 77**. The order of these paths are not important. In the simplest form, the redundant LCS system control means **15** would not have self-testing means **74,75** nor fault detection means **76,77**. However, in the preferred embodiment,

these elements are added to even further reduce the likelihood of an unsafe condition.

[0069] In the simplest form, the operator **30** would press the deck down enabled button **71** which is positioned such that the operator **30** is a safe distance from the variable pinch point gap **9** . If the operator releases the deck down enabled button **71** both redundant paths would provide support to the stacking deck. However, should a single component fail on either redundant path, the variable pinch point gap **9** would still stop decreasing.

[0070] A downstacking sheet stacker **2'** has a variable pinch point gap **9'** which decreases as shown by two positions; first in Figure 10 and then in Figure 12. This is due to the raising of the conveying sheet material removal system **7'** . Unlike an upstacker, see Figure 6, in which gravity naturally tries to decrease the variable pinch point gap 9 , with a downstacking sheet stacker **2'**, gravity is naturally trying to increase the variable pinch point gap **9'** , see Figure 10. As a result, redundancy can be achieved by using only one hydraulic cylinder **11'** or more than one hydraulic cylinders **11', 12'** . A mechanical failure of the hydraulic cylinder **11'** can not cause the variable pinch point gap **9'** to decrease. In typical embodiments, there are a plurality of cylinders due to mechanical engineering requirements.

[0071] This invention could be applied to the variable point point gap (101') that may exist between the bottom side of the conveying sheet material removal system (7') and the floor. However, in the interest of brevity, this will not be described in detail

[0072] The redundancy means **10'** involves using a plurality of hydraulic lock valves **13', 14'** in a redundant LCS system control means **15'** shown in Figure 21. By placing the hydraulic lock valves **13', 14'** in series, they both must be actuated and functioning normally in order to allow pressurized oil to flow into one or more than one hydraulic cylinders **11', 12'**, which in turn decreases the variable pinch point gap **9'**.

[0073] The LCS system control means **15'** shown in Figure 21 allows the operator **30** to press a deck down enabled button **71** in order to electrically activate redundant hydraulic lock valve solenoids **69', 70'** . Said deck down enabled button **71** has redundant right and left deck down enabled contacts **72, 73** that will conduct electrical power down redundant right and left paths to self testing means **74',75'** which then may conduct to redundant right and left fault detection means **76', 77'**. The order of these paths are not important. In the simplest form, the redundant LCS system control means **15'** would not have self testing means **74',75'** nor fault detection means **76',77'**. However, in the preferred embodiment, these elements are added to even further reduce the likelihood of an unsafe condition.

[0074] In the simplest form, the operator **30** would press the deck down enabled button **71** which is positioned such that the operator **30** is a safe distance from the variable pinch point gap **9'**. If the operator releases the deck down enabled button **71** both redundant paths would provide support to the stacking deck. However, should a single component fail on either redundant path, the variable pinch point gap **9'** would still stop decreasing.

[0075] Both LCS system control means **15, 15'** use feedback from various sensor means **17, 17'** in order to detect if a condition exists that requires making sure no power flows to redundant hydraulic lock valve solenoids **69, 70, 69', 70'** . Some of these conditions are classified as self-testing in nature while others are considered to be faults.

[0076] Sensor means **17, 17'** include hydraulic position sensor **18, 18'**, which is activated in one state at a predefined raised position of an associated hydraulic cylinder **11, 12** . Should a failure of support occur in one of the hydraulic cylinders, the associated hydraulic position sensor **18, 18'** will activate to a different state.

[0077] Sensor means **17** may also include the deck down enabled button **71**, which can be monitored to determine if redundant contacts are synchronized and how long they have been in either state.

[0078] Sensor means **17** may also include the operator in position sensor **47**, which can be monitored to determine if its output changes and how long it has been in either state. The operator in position sensor **47** is mounted on remote control means **35** operably connected to said sheet stacker **2 or 2'** . The LCS system control means **15,15'** monitors said operator in position sensor **47** to make sure the operator is a safe distance from the variable pinch point gap **9,9'** while decreasing.

[0079] Sensor means **17** may also include the boom in position sensor **48**, which can be monitored to determine if its output changes. Since the remote control means **35** is swivelly attached to or adjacent to said sheet stacker **2, 2'**, in the preferred embodiment, the boom in position sensor **48** makes sure the boom is in the position shown in Figure 35 as opposed to the location shown in Figure 36. This assures that the operator **30** has a good sightline to the area near the variable pinch point gap **9,9'**.

[0080] Logic means for self testing **78,78'** include but are not limited to: 1) periodic testing the load change hydraulic system **49,49'** integrity, 2) proper functioning deck down enabled button **71**, 3) proper functioning of boom in position sensor **48** and 4) proper functioning of operator in position sensor **47**. If the self-testing conditions are not met, the self-testing contact chain **80,81.80',81'** will not allow power to flow to hydraulic lock valve solenoid(s) **69,70,69',70'**.

[0081] Logic means for fault detection **79, 79'** include but are not limited to: 1) redundant hydraulic lock valve solenoids not being synchronized in the on or off state, 2) the deck down enabled button **71** being active for too long of a period and 3) the operator in position sensor **47** being active for too long of a period. If a fault condition is detected, the fault contact chain **82,83,82',83'** will not allow power to flow to hydraulic lock valve solenoid(s) **69,70,69',70'**.

[0082] The basic form of redundant means **10,10'** for keeping the operator a safe distance from the variable pinch point gap **9,9'** requires that the opera-

tor **30** holds down the deck down enabled button **71** anytime the variable pinch point gap **9,9'** is decreasing. However, there are production line configurations where this is not practical or economical. For instance, in a bundling application where the sheet stacks **6** are built short to form bundles, not shown, the cycle time of the discharge end **4** the stacking deck **3** can be so short that the operator **30** would end up spending nearly all his/her time holding the deck down enabled button **71** .

[0083] In order to solve this problem, the present invention includes an electro-optical light guard means **27** , see Figure 22, that is activated by the operator **30** from outside the light guard perimeter **21** after the operator **30** first visually checks to make sure the area within the light guard perimeter **21** is clear of other personnel and then presses a light guard activation button in order to latch the light guard control circuit **85** to an active state. The term latch indicates that the light guard control circuit **85** will remain active until another event, such as the light guard perimeter **21** being crossed or loss of power to sheet stacker **2,2'** should occur. Thus, after activating the light guard control circuit **85**, the operator **30** may walk away from light guard activation button, leaving the redundant means **10, 10'** in a state allowing a decrease in variable pinch point gap **9,9'**. The light guard activation button is operably connected to the deck down enabled button **71** in the preferred embodiment. This light guard control circuit **85** is operably connected to the light guarded LCS system control means **15'',15'''** which operably controls the redundant means **10, 10'** for selectively preventing a decrease in variable pinch point gap **9,9'**.

[0084] The light guard perimeter **21** is constructed by using one or more light beam (s) **20,20'** that must be redirected multiple times in order to create the appropriate perimeter around portions of the sheet stacker **2, 2'** and portions of the conveying sheet material removal system **7,7'** such that when an operator **30** or other person should break the light guard perimeter **21**, the redundant means **10,10'** can prohibit a decrease in variable pinch point gap

9,9'. Each light beam circuit starts with a light beam transmitter **22** that converts an electrical signal into an optical signal. The redirection is accomplished using an optical repeating node **24,24'**, as illustrated in Figure 24. Unlike conventional mirrors used to redirect the light beam, the optical repeating node (s) **24,24'** uses a repeater pair **28** which consist of an repeater optical receiver **25** which is aligned in the general direction of the incoming light beam **20** . The repeater optical transmitter **26** is electronically connected by repeater circuitry **29** to its associated repeater optical receiver **25** such that the optical signal received by the repeater pair transmitted at the new redirected angle by the repeater optical transmitter **26**. The repeater circuitry **29** needs to meet the electrical engineering requirements of the selected electro-optical components, but in the preferred embodiment, the repeater circuitry **29** does not include any sophisticated clock base electronics, such as micro-controllers or other crystal based components. This is to assure that an optical data signal initiated by the light beam transmitter **22** can only be repeated and received by light beam receiver **23** by properly functioning repeater pair(s).

[0085] The advantage of using the optical repeating node(s) **24,24'** instead of using reflective mirrors **89-89'''** is illustrated in Figures 25 – 30. In Figure **25**, a scaled version of a sheet stacker **2** was drawn in planned view, using AutoCAD with a light guard perimeter **21''** created using a light beam transmitter **22''** , a series of mirrors **89-89'''** at stations **86, 86', 86'', 86'''** and a light beam receiver **23''** at station **86''''**. A dimension of 120 inches has been added to Figure to give the drawing scale. By applying the basic physics of light where the angle of incidence equals the angle of reflection, a perfectly aligned light guard perimeter **21''** was created using light guard beam **87**. Then, in order to show how sensitive a reflective mirror system is to misalignment, the mirror at the first station **86**, which is assumed to be 4 inches in size, see Figure 26, is misaligned by approximately 0.010 inches. This correlates to an angular misdirection of approximately 0.3 degrees.

Then, assuming all the other mirrors **89'-89'''** remain in perfect alignment, which is quite an assumption in heavy industry, the light beam is redrawn as misaligned light guard beam **88**, again using the basic law of reflection. As shown in Figure 26, the angle of reflect is off by approximately 0.3 degrees. In Figure 27, when the light rays arrive at station **86'**, the misaligned light guard beam **88** is off by 2 3/8 inches. At station **86''**, in Figure 28, the misaligned light guard beam **88** is off by 4 1/16 inches. At station **86'''**, in Figure 29, you would now need over a 20 inch mirror, since the misaligned light guard beam **88** is over 10 inches off center line. By the time the misaligned light guard beam **88** gets to the light beam receiver **23''** in Figure 30, it is off by over 4 inches. In addition to this tremendous sensitivity to angular misalignment, a reflective mirror system also has the poor characteristic of accumulating misalignment error. That is, if the mirrors **89'**, **89''** at station **86'** and **86''** both have a misalignment, the error would add to each other.

[0086] The optical repeating system of the present invention essentially uses a transmitter and receiver to create each straight section of the light guard perimeter **21**. Since the preferred optical transmitters generates a cone of light, the preferred optical receiver has a lens to allow for rays of light to enter to a certain amount of angular misalignment, an angular misalignment of 3 degrees or more are easily achieved. In addition to the 10 times or more forgiveness to misalignment, the optical repeating system does not accumulate misalignment error. By referring to Figure 24, it is clear that any misalignment of the rays of beam coming into repeater optical receiver **25** has no impact on the alignment of repeater optical transmitter **26** . The only disadvantage of the optical repeating system compared to the reflective mirror system is the fact that the repeating nodes typically require an external power supply.

[0087] In the preferred embodiment, the light guard means **27** , includes two light beam **20,20'** circuits, separated vertically as shown in Figure 23. The

number of light beams, their vertical locations and the distance of the light beams from the variable pinch point gap **9,9'** are based on using safety standards as a guideline and computer simulated biomechanical analysis of trip scenarios.. When using two beams, it is preferred to have the top beam **20** and the bottom beam **20'**±s12v1P directed in opposite direction, to further eliminate the possibility of cross talk between the two beams.

[0088] A load change safety system **1"** of the present invention for a sheet upstacker **2** having a stacking deck **3**, formed with a discharge end **4**, for discharging sheet material **5** onto and building a sheet stack(s) **6** on a conveying sheet material removal system **7**, formed with a receiving means **8** may consist of the following elements.

[0089] In such systems, a variable pinch point gap **9** is formed by relative motion between the discharge end **4** of the stacking deck **3** of the sheet stacker **2** and the receiving means **8** of the conveying sheet material removal system **7**. In the present invention, redundant means **10** is provided for selectively preventing a decrease in the variable pinch point gap **9**.

[0090] To guard personnel from this pinch point gap **9**, an electro-optical light guard means **27** is operably connected to the redundant means **10** with one or more redirections of one or more light beams **20** to create a light guard perimeter **21** for guarding portions of the sheet stacker **2** and portions of the conveying sheet material removal system **7**.

[0091] The electro-optical light guard means **27** includes one or more light beam transmitters **22** and one or more light beam receivers **23**. The electro-optical light guard means **27** further includes one or more optical repeating nodes **24 or 24'** using an optical receiver **25** and an optical transmitter **26** for creating the redirection of the light beam(s) **20**.

[0092] The redundant means **10** also includes a plurality of hydraulic cylinders **11** and **12** for raising and lowering the stacking deck **3**. The hydraulic cylinders **11** and **12** must be of adequate strength such that should one cyl-

inder **11** or **12** fail to provide a support for the stacking deck **3**, the remaining cylinder **11** or **12** can support the weight of the stacking deck **3**.

[0093] A plurality of valves **13** and **14** are provided wherein at least one valve **13** or **14** is independently connected to each of the cylinders **11** and **12** which may selectively and alternatively permit and prevent flow of fluid from those of the hydraulic cylinders **11** and **12** which are operating normally and have not failed, thereby resulting in rapidly preventing the variable pinch point gap **9** from narrowing.

[0094] A light guard control means **15"** is operatively connected to the electro-optical light guard means **27** and operatively and independently connected to each of the valves **13** and **14** for alternatively permitting and preventing flow of fluid from the hydraulic cylinders **11** and **12**.

The load change safety system **1'''** for a down stacker system is nearly identical to the load change safety system **1"** for an upstacker system as described immediately above, but with the following changes.

[0095] The redundant means **10'** include one or more hydraulic cylinders **11'**, **12'** for raising and lowering an elevating platform **16'** of the conveying sheet material removal system **7'** instead of being mounted on the upstacker **2**.

[0096] Further, while only a single cylinder is required for raising the platform **16'**, generally two or more cylinders are provided for other reasons. In such systems, a plurality of valves **13'** and **14'** are provided wherein the valves **13'** and **14'** are operatively connected to each other and the cylinders **11'** and **12'** by means such that all of the valves **13'** and **14'** must simultaneously be activated and operate normally for selectively and alternatively permitting and preventing flow into the hydraulic cylinders **11'** and **12'** which are operating normally and have not failed, thereby preventing the variable pinch point gap **9'** from narrowing.

[0097] In the present invention the pinch point gap **9'** is protected by a light guard control means **15"'** operatively connected to the electro-optical light guard means **27** and operatively and independently connected to each of the

valves **13'** and **14'** for alternatively permitting and preventing flow of fluid into the hydraulic cylinders **11',12'**.

[0098] Since any electro-optical component can fail and the failure can result in a sensor output in the on or off state, the electro-optical light guard means **27** requires a modulated signal detection means **34** such that a failure of an electro-optical component in either state will send the same light guard output signal as if the light guard perimeter **21** is blocked. A modulated transmitter circuit is connected to the light beam transmitter(s) **22** such that the modulated signal detection means **34** can generate a defined modulated optical signal **33** in series around the light guard perimeter **21** via optical repeating nodes **24,24'**. A receiver decoding circuit **31** feeds back to the modulated signal detection means **34** the electrical equivalent of the defined modulated optical signal **33**. The modulated signal detection means **34** can determine if the modulated signal has been properly received. Since the signal must be modulated, a failure of any electro-optical component in either the on or off state can be interpreted as a blocked light guard perimeter **21** and the associated signal sent as the light guard output signal **43** . Of course, an actual blockage of the light guard perimeter will generate the proper signal sent as the light guard output signal **43** .

[0099] The light guard output signal **43** is operably connected to light guarded LCS system control means **15'', 15'''** . When the light guard output signal **43** indicates a blockage of the light guard perimeter **21** , the associated light guard control circuit **85** will be deactivated which operably controls the redundant means **10,10'**; preventing a decrease in the variable pinch point gap **9,9'** .

[0100] In addition to making sure that the a failure of any electro-optical component results in a fail-safe mode, the modulated signal detection means **34**, in the preferred embodiment, is also connected to the fault detection mean **76,77** since certain failures can be detected.

[0101] In the preferred embodiment, there is an independent modulated signal detection means **34** for each light guard beam **20, 20'** .

[0102] In prior art, Figures 1, 2, 3 & 4, the light guard perimeter was created using two way redirections of the light guard light beams and fixed post mounted to the ground as the starting and stop points for the light guard perimeter. In addition to not providing an adequate distance between the light guard perimeter and the pinch point of concern, this system results in the nuisance of having a floor mount post in the way of the operator **30** .

[0103] This invention teaches the idea of using a four way redirection of the light guard light beams and starting and stopping points for the light guard perimeter mounted to the machine. This allows a greater distance between the light guard perimeter and the pinch point of concern. However, while using a floor mount optical repeater node as shown in Figure 34 would provide the greater distance, it would still not solve the problem of the nuisance of having a floor mounted post **96** in the way of the operator.

[0104] This invention includes a solution to this problem, as shown in Figure 35. A remote control means **35** is connected to the sheet stacker **2** and positioned so that the operator **30** has a good visual vantage point for observing the variable pinch point gap **9,9'** and the light guard perimeter **21**. The remote control means **35** includes deck down enabled button **71** which in the preferred embodiment both allows basic enabling of the decreasing of variable pinch point gap **9,9'** and also the activating the light guard control circuit **85** .

[0105] The remote control means **35** is connected to the movable part of the boom **37** which in turn is swivelly attached to or adjacent to the sheet stacker **2, 2'** . This give the operator the ability to move the moveable part **37** of boom **36** from the boom in position location **44** to the boom out of position location **45** as shown in Figure 36. From this illustration, we can see how the operator does not have any post in his/her way. Also, there are of-

ten other controls on the remote control means **35** that are better adjusted when the operator is in this boom out of position location **45** .

[0106] By mounting one of the optical repeating nodes **24'** to the bottom of the remote control means **35** , which is operably connected to the movable part of the boom **37**. The resulting configuration provides a completed light guard perimeter **21** when the boom **36** is at the boom in position location **44**, while also effectively eliminating the possibility of the light guard control circuit **85** being activated when the remote control means **35** is swiveled to the boom out of position location **45**. This works well with the design intent of only letting the operator **30** activate the light guard control circuit **85** when the boom **36** is in the boom in position location **44** .

[0107] In the preferred embodiment there is also a boom in position sensor **48** , shown in Figure 35, mounted near the elbow of the boom **36** . This allows the basic LCS system control means **15,15'** to make sure the remote control means **35** is properly positioned before allowing the deck down enabled button to enable the variable pinch point gap **9,9'** to decrease.

[0108] In the preferred embodiment there is also an operator position sensor **47** , shown in Figure 35 that makes sure the operator **30** is standing in front of the remote control means **35** as not to be able to activate the light guard control circuit **85** from within the light guard perimeter **21** .

[0109] The light guard means **27** presents the challenge when building full stacks **6'** because of the need to eventually convey the completed full stacks **6'** from within the light guard perimeter **21** to outside the light guard perimeter **21** on the conveying sheet removal system **7,7'**. A technique exists called 'muting' by which the light beam blockage is 'ignored' by the control means when the control means 'thinks' the material is exiting through the light beams such that the light beam then automatically becomes active after the control means 'thinks' the material has successfully exited. This technique is considered inadequate for the sheet stacker **2** application since it is possible for an operator to enter the light guard perimeter **21** at the same

time the full stack **6'** is blocking light beams **20, 20'** resulting in the operator being able to go undetected from the outside to the inside of the light guard perimeter **21** .

[0110] This!invention solves the problem of transporting the full stacks **6'** from inside to outside the light guard perimeter **21** by configuring the light guard means **27** in a relative fashion to the conveying sheet removal system **7,7'** such that it naturally works with the operators **30** work habits to minimize the impact of needing to press a light guard activation button in order to latch the light guard circuit **85** to an active state after the full stack **6'** has reset the light guard circuit **85** to a deactivated state.

[0111] Figure 37 shows a standard configuring of the light guard means **27** in a relative fashion to the conveying sheet removal system **7** . The important parameter is tie distance **D1 46** which is the distance from the face of the discharge end **4** of the stacking deck **3** where the full stack **6'** is being built to the location where the light beams **20'', 20'''** cross over the conveying sheet removal system **7**. The light beams **20'', 20'''** are the upper and lower beams in the preferred embodiment created by optical repeating nodes **24** positioned at station locations **40,41** shown in Figure 35. In the configuration shown in Figure 37, there is no pallet and/or dunnage inserting system **95** . As a result, the operator **30** is typically required to manually place the pallet **51** and/or dunnage **50** every time the full stack **6'** is transported an adequate distance downstream on to the conveying sheet removal system **7** and before the stacking deck **3** makes the deck down cycle **56''**, referred to in Figure 13 for typical load change cycle **56** sequence. As a result, it is natural for the parameter **D1 46** to be somewhat longer than the length **L 91** of the largest full stack **6'** size so the light guard perimeter **21** is not blocked while full stack **6'** is being built, however, the parameter **D1 46** should allow the full stack **6'** to block and exit the light guard perimeter **21** in short order during the load ejection **56'** allowing the operator **30** to also cross the light guard perimeter **21** and place the pallet **51** and/or dunnage **50** before the as-

sociated deck down cycle **56''** begins. As a result, the operator **30** and the full stack **6'** are both breaking the light guard perimeter at approximately the same time, and since the operator **30** is in the vicinity of the remote control means **35** , he/she can easily press a light guard activation button **71** in order to latch the light guard circuit **85** to an active state.

[0112] This invention includes a configuration of the light guard means **27** to allow for a common production line configuration that includes a pallets and/or dunnage inserter system **95** similar to the one illustrated in Figure 38. When a pallets and/or dunnage inserter system **95** exist, the operator **30** has the luxury of not having to be present at the discharge end **4** or the stacking deck **3** during any part of the load change cycle **56** . This is because the pallet **51** and/or dunnage **50** can be placed on the inserter system **95** during the time while the full stack **6'** is being built. During the load change cycle **56** the pallets and/or dunnage inserter system **95** automatically indexes the pallet **51** and/or dunnage **50** during the load ejection cycle **56'** in such a way as to properly position the pallet **51** and/or dunnage **50** to receive the next full stack **6''** to be created. If the light beams **20'', 20'''** were to cross over the conveying sheet removal system **7** at the distance **D1 46** , the operator **30** would be required at the remote control means **35** to press a light guard activation button **71** in order to latch the light guard circuit **85** to an active state.

[0113] Figures 38 and 39 illustrate the solution to this problem. The light beams **20'', 20'''** that cross over the conveying sheet removal system **7** are moved downstream to the distance **D2 46'** which is the distance from the face of the discharge end **4** of the stacking deck **3** where the full stack **6'** is being built. The distance **D2 46'** is somewhat longer than twice the longest length **L 91** of the full stacks **6'** that are planned for production on sheet stacker **2**. This distance **D2 46'** allows for completed full stack **6'** to be transported during the load ejection cycle **56'** with its leading edge to stop at approximate location **P 90** using conveying system control means **92**, which

is operably connect to a travel limit control means **38** . Since the complete full stack **6'** is still within the light guard perimeter **21**, the latch light guard circuit **85** may remain active and the deck down cycle **56''** can be completed without the need for operator **30** attention.

[0114] Upon completion of the deck down cycle **56''** , the next new full stack **6''** begins to be built, at which point, the operator has two options for transporting the complete full stack **6'** from inside to outside the light guard perimeter **21**. The conveying system control means **92** may simply wait for the operator **30** to press a load release control **39** at which point the conveying system control means **92** which is operably connected to a travel limit control means **38** releases new full stack **6'** for transport downstream. Alternatively, the conveying system control means **92** may be set to a mode that allows the light guarded LCS system control means **15'',15'''** to operably signal the conveying system control means **92** when the deck down cycle **56''** has been completed which then will automatically release new full stack **6'** for transport downstream.

[0115] Figure 39 illustrates in schematic form the functional relationship of conveying system control means **92** . There are many well known ways to implement travel limit control means **38** such that complete full stack **6'** stops at location **P 90** . One common method is to apply a braking section to the rollers integrated into the conveying sheet removal system **7**. Typically, a feedback sensor, full stack at position **P** sensor **93** is connected to conveying system control means **92** . The two optional release signals are also shown in Figure 39. The one coming from the manual activated load release control **39** and the other from light guarded LCS system control means **15'',15'''**, which can monitor the position of the stacking deck **3** . In the preferred embodiment, the conveying system control means **92** would include a selectable mode setting to allow the operator **30** to change release modes depending on the current orders being run in production.

[0116] A similar but alternate configuration of the system shown in Figure 38 is shown in Figure 40. The light beams **20'', 20'''** that cross over the conveying sheet removal system **7** are moved downstream to the distance **D3 46''** which is the distance from the face of the discharge end **4** of the stacking deck **3** where the full stack **6'** is being built. The distance **D3 46''** is substantially longer than the longest length **L 91** of the full stacks **6', 6'', 6'''** that are planned for production on sheet stacker **2** . !This distance **D3 46''** allows a plurality of completed full stack **6', 6''** to be transported and stored within the light guard perimeter **21** making sure the leading leading edge of full stack **6'**!stops at approximate location **P 90** using conveying system control means **92**, which is operably connected to a travel limit control means **38**. Since the complete full stacks **6', 6''** are still within the light guard perimeter **21**, the latch light guard circuit **85** may remain active and the deck down cycle **56''** can be completed multiple times without the need for operator **30** attention. This is advantageous in production line configurations where there are no pallets **51** and/or dunnage **50** required under full stacks **6', 6''**.